

Physics

Solutions

Trial Examination

HSC Course

2008

General Instructions

Reading time - 5 minutes

Working time - 2 hours 15 minutes

Board-approved calculators may be used.

Write using blue or black pen.

Draw diagrams using pencil.

Formulae sheets and a Periodic Table are provided with this question paper.

Answer all questions in the spaces provided.

Total Marks (75)

This paper has one section with two parts:

Section I

Total marks (75)

Part A

15 marks – attempt questions 1 - 15

Part B

60 marks – attempt questions 16 - 27

Section I

Part A

Multiple Choice Answers

For questions 1 to 15 place a cross (X) in the column which matches your choice.

Question	A	B	C	D
1		X		
2			X	
3				X
4			X	
5		X		
6	X			
7			X	
8			X	
9		X		
10	X			
11		X		
12	X			
13				X
14				X
15			X	

Section I

Part B

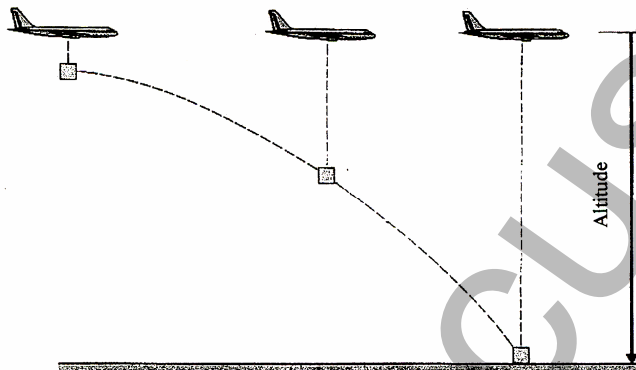
Total marks (60)

Attempt questions 16 – 27

Allow about 1 hour 45 minutes for this part

Question 16 (4 marks)

A plane drops emergency food rations to the Red Cross in Central Africa. The plane is flying at 216 kmph and keeping a constant altitude above the plains below.



The person dropping the rations measures the time of fall to be 15 seconds to impact.

- (a) Calculate the final vertical velocity of the food rations just before impact. 1

$$v = u + at = 0 + 9.8 \times 15 = 147 \text{ ms}^{-1}$$

i.e. vertical velocity at impact is 147 ms^{-1}

- (b) Calculate the plane's altitude. 1

$$S = ut + \frac{1}{2}at^2 = \frac{1}{2} \times 9.8 \times 15^2 = 1102.5 \text{ m}$$

i.e. plane's altitude was 1102.5 m

- (c) Calculate the horizontal distance travelled by the rations during the fall. 1

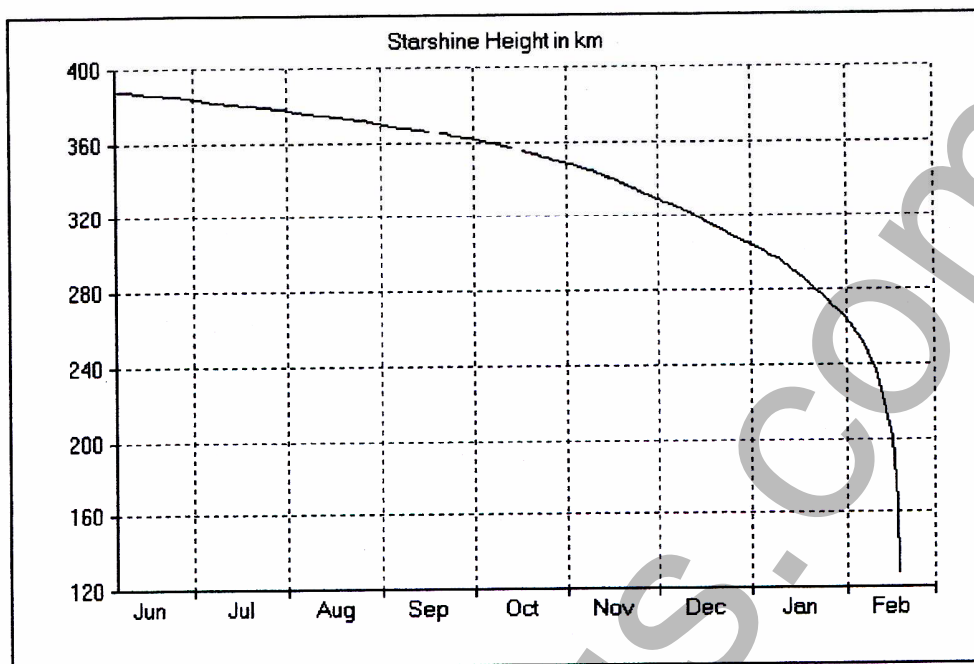
Horizontal velocity remains at 216 kmph (60 ms^{-1}). So rations move sideways at 60 ms^{-1} for 15 seconds i.e. a distance of $60 \times 15 = 900 \text{ m}$

- (d) Compare the horizontal distance travelled by the plane and the rations during the fall. Include a reference to any assumptions made. 1

Both the plane and the rations share the same horizontal velocity (if we ignore air resistance) throughout the 15 second time interval. Thus they both travel the same horizontal distance.

Question 17 (3 marks)

The graph below shows the orbital decay of the satellite, Starshine. The height is plotted against the date. The altitude in early June was 385 km above the Earth's surface.



- (a) Define the term “orbital decay”.

1

Orbital decay is the loss of altitude of a satellite when orbiting Earth.

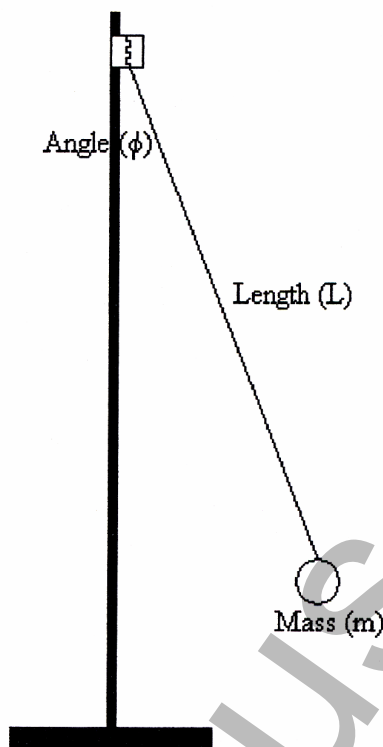
- (b) List TWO factors causing the changing rate of orbital decay of Starshine from June to February. 2

Increasing atmospheric drag due to increasing atmospheric density as altitude decreases; increasing gravitational force as satellite moves nearer to the centre of the Earth.

Question 18 (6 marks)

Two students carried out an investigation to determine the acceleration due to gravity using pendulum motion.

They set up the equipment as shown in the diagram below:



Their results allowed them to construct the following table. One value was omitted.

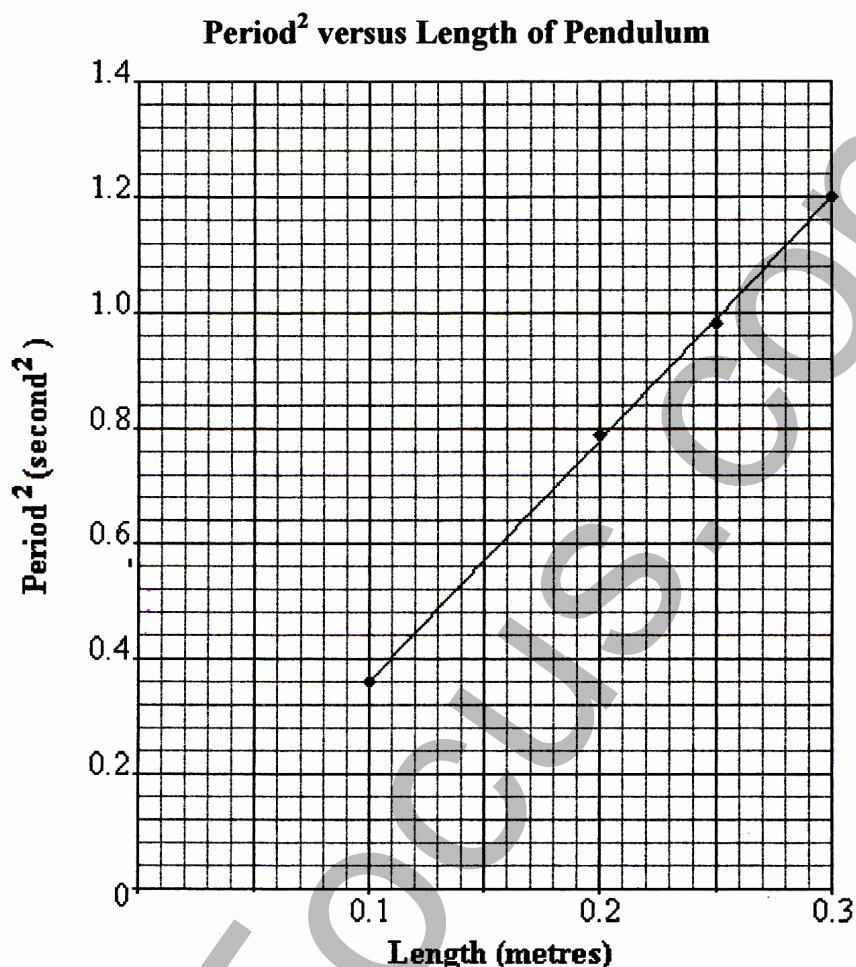
Length (L) (metres)	Period ² (T ²) (seconds ²)
0.10	0.36
0.15	Not calculated
0.20	0.79
0.20	0.97
0.30	1.2

Students carried out a practical to determine how the length of a pendulum influences the period of the pendulum's motion. As part of their report they produced the following graph.

Question 18 continues on next page.

Question 18 (continued)

The results from the table were used to plot a graph of period² against length as shown below:



- (a) State the value and units for the missing data.

1

0.57 s^2

- (b) Given that the formula for the period of a pendulum is

$T = 2\pi\sqrt{L/g}$ where T is the period; L is the length; g is acceleration due to gravity;
describe how the value of acceleration due to gravity can be determined from the gradient of the graph.

2

Beginning with the formula, squaring both sides and re-arranging gives T^2/L is a constant. The graph of T^2 vs L is a straight line so the constant is equal to the gradient of the line.

Thus the gradient is equal to $4\pi^2/g$, so g can be calculated.

Question 18 (continued)

- (c) Calculate the value of acceleration due to gravity in this situation. 2
Using the above method, $g = 9.4 \text{ ms}^{-2}$

- (d) Given that the average value of acceleration due to gravity is 9.80 ms^{-2} , and that the students used accurate and reliable methods to obtain their data, suggest a reason why the students' value for the acceleration due to gravity is NOT 9.80 ms^{-2} . 1

A possible reason for the lower value of g calculated could be that the experiment was performed at altitude.

Question 19 (7 marks)

- (a) Distinguish between inertial and non-inertial frames of reference. 2

Inertial frames of reference are those in which the observer is not being accelerated i.e. is moving with constant velocity or is stationary. Non-inertial frames of reference are those in which the observer is being accelerated.

- (b) Calculate the mass of a proton when it is travelling at 75% of the speed of light. 2

Use mass dilation formula with $v = 0.75c$ and $m_0 = 1.66 \times 10^{-27} \text{ kg}$; gives $m_v = 2.59 \times 10^{-27} \text{ kg}$

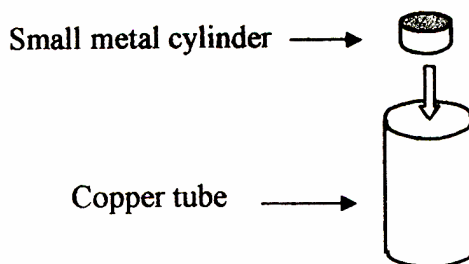
- (c) Einstein's Theory of Special Relativity made predictions about time, length and mass measurements for objects travelling at speeds approaching the speed of light.

Discuss the experimental evidence for ONE of these predictions. 3

e.g. time will "run slowly" on board a spacecraft which is travelling at relativistic speeds. This means that an observer on Earth may measure 10 years as having passed, but for an astronaut on the spacecraft only 8 years may have passed. Time has dilated for the astronaut. This phenomenon can be proven by using synchronised atomic clocks (one on earth and the other on a high speed craft orbiting the Earth). The clock on the craft runs slower than the clock on Earth.

Question 20 (5 marks)

When a small metal cylinder is dropped into one end of the copper tube shown below, it falls freely under the action of gravity.



Yet a small magnet of identical dimensions takes much longer to fall through the tube.

(a) Explain this observation.

3

As the magnet falls it induces an emf in the copper tube (lines of flux are being cut by the conductor). This emf induces currents in the conductor. These are eddy currents and they flow in such a direction as to oppose the motion which produced them. This means that they will oppose the motion of the falling magnet i.e. slow it down. The metal cylinder is not magnetic and therefore does not induce an emf.

(b) Outline how a similar phenomenon is used in certain braking mechanisms.

2

e.g. falling capsule on Space Probe ride. The metal sides of the capsule pass through magnetic fields generated by coils. The emf induced produces eddy currents and the capsule is slowed in its fall.

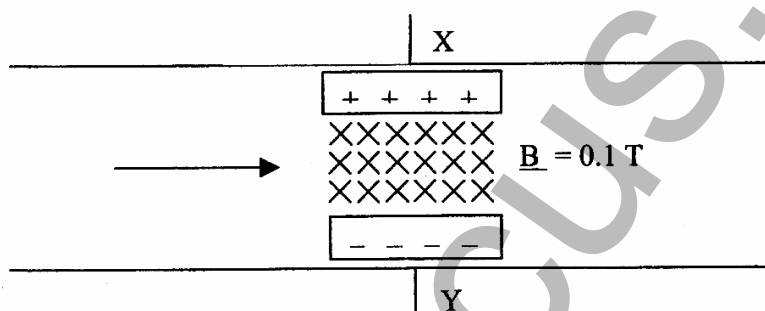
Question 21 (6 marks)

- (a) Outline Thomson's experiment to measure the charge / mass ratio of an electron.

3

Thomson allowed electrons to pass through a region where there was both an electric field and a magnetic field. He adjusted the strengths and directions of the fields so that the electron was undeflected. From this he was able to determine the velocity of the electrons. He then turned off the electric field and measured the radius of curvature of the path of the electrons when they were deflected by the magnetic field. Using this information, and the speed of the electrons, he was able to determine a value for the ratio of the charge to mass for the hitherto unknown particle.

- (b) An electron is accelerated to a speed of $1 \times 10^4 \text{ ms}^{-1}$ inside a cathode ray tube. The electron enters a region of crossed magnetic field of 0.1 T and electric fields as shown in the diagram below.



Calculate the potential difference across the parallel plates, XY, required to allow the electron to pass undeflected through the electric and magnetic fields. The distance between the plates is 10 cm. **3**

$$F_E = Eq \quad \text{and} \quad F_B = Bqv \quad \text{gives} \quad E = vB$$

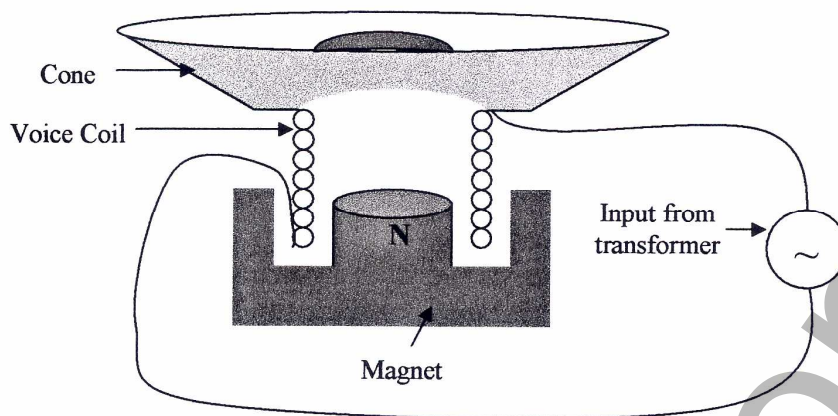
$$\text{But } E = V/d \quad \text{so} \quad V = vBd$$

$$\text{From the data} \quad V = 1 \times 10^4 \times 1 \times 10^{-1} \times 1 \times 10^{-1}$$

$$\text{So} \quad V = 100 \text{ V}$$

Question 22 (4 marks)

The diagram below shows a simplified section of a loudspeaker.



- (a) Using principles of physics, explain how the cone of this device is made to vibrate. 2

The voice coil carries pulses of electricity originally generated by sound waves being captured by a microphone. These electrical pulses create a constantly changing magnetic field in the vicinity of the coils. The magnet attracts and repels the coil with varying strength according to the size of the generated magnetic field. This causes the cone of the speaker to vibrate, thus creating sound waves.

- (b) Discuss how ONE other electrical device makes use of the same physics principles that is involved in the operation of the loudspeaker. 2

The principle involved is the motor effect. The motor effect is put to work in both motors and meters. The presence of a current-carrying coil in a magnetic field is common to both. In both devices the coil experiences a turning moment due to the fact that the coil experiences a force at a distance from a fulcrum, or rotational axis.

Question 23 (5 marks)

- (a) Excess heat in transformers can be a major problem. Describe the cause of this excess heat and suggest a method for minimising the problem. 2

The constantly fluctuating magnetic field means that eddy currents will be induced with the coils of the transformer. Eddy currents are a source of heat but they can be minimised by laminating the coil i.e. using “slices” of iron separated by insulating material rather than solid “slabs” of iron. The use of ferrites also reduces eddy currents as the ferrites are less conducting than soft iron.

- (b) Discuss why some electrical devices in the home that are connected to the mains domestic power supply make use of a built in transformer. 3

Household electricity supply is 240 V AC. Not all electrical devices run on this supply. Some devices use DC at a much lower voltage i.e. 6 – 12 V DC. Devices that fit into this category are radios, computers, Playstations etc. Some devices also require higher voltages e.g. TV picture tubes. Thus transformers are required to either step up or step down the voltage.

Question 24 (4 marks)

- (a) Cathode rays were first investigated over 150 years ago. Experiments since that time have indicated that cathode rays have the following properties:
- Cathode rays travel in straight lines
 - Cathode rays are charged particles
 - The charge on the cathode rays is negative
 - Cathode rays are able to transfer energy and do work

- (a) For any TWO of these properties, describe how they can be demonstrated in the laboratory using discharge tubes. 2

Possible answers include the use of a Maltese Cross to establish shadows, thus indicating that the cathode rays move in straight lines; deflection in electric and magnetic fields to demonstrate charge; paddle wheel demonstration to show that the “rays” possess momentum; etc.

- (b) Justify the conclusion of the demonstrations you chose in (a). 2
- e.g. Maltese Cross. When the cross is lying flat in the tube it provides no obstruction to the passage of the rays and they strike the glass beyond the anode. This causes a uniform glow in the glass. However, when the Maltese Cross is upright, it provides a barrier to some of the rays and a shadow forms on the glass beyond the anode.*

Question 25 (5 marks)

Outline Einstein’s explanation of the photoelectric effect. 5

Einstein was able to provide an explanation for the photoelectric effect which make up for the inadequacies of the wave model. He suggested that the incident radiation consisted of a stream of photons, or individual packets of energy. Each photon was characterised by a particular frequency, f , which was linked to the energy of the photon by Planck’s equation, $E = hf$. When the photon was incident upon the metal surface, it underwent a perfectly elastic collision with an electron within the surface. Thus the electron absorbs all of the energy of the incident photon. Each metal surface was characterised by a certain work function, which represent s the amount of energy an electron needs to escape from the surface. If the energy of the photon exceeded this work function, the electron would escape with an amount of energy equal to the difference between the energy of the photon and the work function of the metal. If the electron did not receive sufficient energy from the photon to overcome the work function, then it would not escape. Since energy is determined y frequency, there exists a threshold frequency below which electrons will not be emitted.

Question 26 (6 marks)

This question refers to the electrical resistivity of different materials at room temperature.

Material	Approximate Resistivity (ohm centimetres)
Diamond	10^{14}
Glass	10^{10}
Pure silicon	10^5
Doped silicon	10^3
Pure germanium	10^2
Doped germanium	10^0
Copper	10^{-6}

Both silicon and germanium are semiconductor materials.

- (a) Distinguish between pure silicon and doped silicon.

2

Pure silicon contains only silicon atoms covalently bonded in a network. Doped silicon is a sample of silicon atoms in which either a Group III or Group V element's atoms have been added in a concentration of about 1 in every 200 000 silicon atoms.

- (b) By referring to the table, explain how doping a semiconductor can change its electrical properties.

4

Doped silicon is 100 times less resistive / more conductive than pure silicon. The addition of a group V atom provides 4 outer shell bonding electrons and one electron which is surplus to bonding requirements. This unbound electron is free to move within the network (lattice) of silicon atoms, thus enhancing conductivity.

Question 27 (5 marks)

Discuss how shortcomings in available communication technology led to the invention of the transistor. 5

Solid-state devices have been used since the beginning of electronics. For example, the “crystal set” was a type of radio receiver which utilised a solid-state (crystal) rectifier. But with the development of reliable and efficient vacuum tubes, there was little interest in solid-state electronics for several decades.

The demands of the new radar technology during and in the years after WWII, however, sparked renewed interest in solid-state devices. In 1948 the Bell Laboratories in the USA developed the transistor, which is one semi-conducting material sandwiched between two thin layers of the other type i.e. pnp or npn. Methods of purifying silicon improved and it began to take over from germanium as the semiconductor of choice. It has three significant advantages over germanium: it is more readily available and less expensive than germanium; it retains its semi-conducting abilities at higher temperatures than germanium; and it forms a strongly adhering, electrically insulating oxide film when it is heated at high temperatures in the presence of oxygen. This third property was to prove very useful in the manufacture of integrated circuits (ICs).

By the 1960s, transistors largely replaced the old-fashioned vacuum tubes in virtually all of their applications. Solid-state devices were found to be less fragile, much smaller and more reliable. This allowed for their use in portable devices, like the first “transistor radios” which were small and portable (they could fit in your shirt pocket). They were the forerunners of today’s iPods and MP3 players. Miniaturisation has allowed the production of integrated circuits on silicon chips and so caused the computer revolution which affects all of society.